OVERVIEW OF MEDICAL OCCUPATIONAL EXPOSURE ISSUES IN THE EUROPEAN COUNTRIES

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1. INTRODUCTION

The aim of this paper is to set the scene for this, the 6th European ALARA Network (EAN) Workshop, the topic of which is Occupational Exposure Optimisation in the Medical Field and Radiopharmaceutical Industry. As with previous Workshops, apart from providing a forum for the exchange of information and experiences, it has an objective, the identification of recommendations to the European Commission, regulatory bodies and other involved parties. The previous five Workshops have given rise to some 35 recommendations. Stemming from these several new projects have been started. For example

- The 2nd Workshop on "Good Practices in Industry and Research [1] identified the need to improve the mechanisms for improving feedback and learning the lessons from accidents and incidents. This lead to an EC pilot study, European Union Radiation Accident and Incident Data Exchange Project (EURAIDE) which is covered in a later paper [2].

- The 3rd Workshop on Managing Internal Exposure [3] gave rise to an EC project : Strategies and Methods for Optimisation of Internal Exposure (SMOPIE) of workers from industrial processes involving naturally occurring radioactive material.

- The 5th Workshop, "Industrial Radiography – Improvements in Radiation Protection" [4], has given rise to an EC supported Joint Working Group from EAN and the European Non-Destructive Testing Society to take forward improvements in industrial radiography.

The progress of these initiatives can be followed in the EAN newsletter [5].

It is to be hoped that the recommendations from this Workshop, will similarly lead to useful programmes of work. In order to facilitate the development of recommendations, the Workshop Programme includes two sessions where participants will split into a number of Working Groups to develop ideas. These will be reported on in the final session of the programme and we will attempt to bring together the strands into a coherent set of recommendations.

As a further aid to this process this paper briefly reviews the overall subject of each session and puts forward some questions that might be addressed in the session and subsequent Working Groups.

2. OVERVIEW OF OCCUPATIONAL DOSE DISTRIBUTIONS

Medical uses of radiation are some of the oldest uses of radiation. Whilst a large fraction of medical radiation work uses well established technology there is an ever expanding envelop of cutting edge technology that brings with it new challenges to the optimisation of occupational exposure control. Some challenges relate to the equipment and use procedures, whilst others relate to widening of the scope of disciplines and specialists using radiation beyond those that have had radiation protection as an element in their professional training.

Medical uses are generally split into diagnostic radiology, radiotherapy, nuclear medicine and radiopharmaceutical uses. Similarly the exposed workers can be broken down into radiologists, radiographers, clinicians, nurses, pharmacists, scientists, technicians, research workers etc. However, the terminology and the way data is grouped vary significantly from one country to another, making comparisons difficult. There are also significant differences in monitoring practices making it important to be clear about parameters that underlie dose data. An obvious example is whether or not the personal dosimeter is worn external to any protective lead apron or underneath it. Further examples will become apparent with the data presented below.

2.1 UNSCEAR

Every five years the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) review occupational exposures (and other routes world-wide). The last such report was published in 2000 [6] and covered the period 1990 – 1994, giving data for that period and comparative data for earlier 5 year periods.

Table 1. Trends in monitored workers and average doses world-wide in the medical sector

Period	Monitored Workers (thousands)	Average Annual Individual Dose (mSv)
1975-79	1280	0.78
1980–84	1890	0.60
1985-89	2220	0.47
1990-94	2320	0.33

World-wide there are estimated to be some 2.32 million exposed workers in the medical sector, which makes them the largest group of workers (approximately 50%) occupationally exposed to man-made sources. Table 1 shows the rise in numbers of workers from 1975 to 1994, together with the satisfying fall in average annual individual dose to 0.33 mSv. However the later figure needs a degree of caution, in that in medicine the individually monitored population includes a large proportion where the reason for monitoring might be described as “reassurance monitoring”. These individual’s personal dosimeters rarely record any dose. To address this confounding factor, the latest UNSCEAR Report also estimated average individual doses to measurably exposed workers (i.e. non zero doses). For medical uses of radiation this was 1.4 mSv, which can be compared to 1.0 mSv for education/veterinary, 2.2 mSv for industrial uses and 3.1 mSv for nuclear fuel cycle.

There is considerable variation around the world regions as shown in table 2.

Table 2. UNSCEAR: Variations in dose data by Region in the medical sector

Region	No. of workers (Thousands)		Average annual individual doses (mSv)	
	Monitored	Measurably exposed	Monitored	Measurably exposed
E&SE Asia	44	28	1.00	1.56
Eastern Europe	420	145	0.44	1.25
Indian Sub Continent	26	14	0.79	1.44
Latin America	22	9	1.26	3.30
OECD (except USA)	870	160	0.20	1.10
USA(1)	870	160	0.20	1.10
Remainder	61	27	2.10	4.60
TOTAL(2)	2,320	550	0.33	1.39

(1) USA data was not directly available and previous data indicated it to be close to the rest of the OCED.
(2) Rounded figures.

Europe is not a specific region within the UNSCEAR data and perhaps the most representative is that for the OECD countries (excluding the USA). Whilst this aggregated data gives some benchmarks and clearly shows differences related to the states of development of radiation protection infrastructures, it is only when one gets down to the country data that it is possible to look at dose distributions that become meaningful. However in all cases careful reading of the table footnotes and texts in USNCEAR is advisable.

Data specific to radiopharmacie is not specifically identified, being subsumed within radioisotope production.

2.2 ESOREX

The European Commission has funded a project entitled European Study of Occupational Radiation Exposure (ESOREX). Its purpose was to survey in each EU Member State, plus Iceland, Norway and Switzerland.

(i) the administrative systems used to register individual occupational radiation exposure, and
(ii) the numbers of occupationally radiation exposed persons and the dose distributions for the year 1995.

Although a number of countries were not able to provide the data in the required format, the final report [7] currently provides the most coherent overview of occupational exposure in Europe. A follow on project, ESOREX EAST has been started which covers potential EU Applicant countries; Bulgaria, Estonia, Hungary, Latvia, Lithuania, Poland and Slovak Republic.

Table 3 provides a summary of key data for occupational exposure in medicine from the original ESOREX project [7]. As indicated earlier there are a number of confounding factors that make direct comparisons between countries difficult and for the detail of this the reader is referred to the project report. Nevertheless a few generic observations can be made.

(a) workers exposed in the medical sector are, with the notable exception of the UK and Sweden, a very large percentage of the total workforce that is occupationally exposed to radiation (typically higher than the overall 50% in UNSCEAR). The data from the UK is anomalous and is explained in section 2.3.
(b) The average annual individual doses, both for all monitored workers and measurably exposed workers varies from country to country by up to about a factor of 10. This indicates either significantly different individual monitoring practices or different levels of implementation of the radiological protection system.
(c) The above differences are also evident in the numbers of people in the higher dose bands. Whilst some instances may be due to irradiation of badges whilst they were not being worn, the overall profile suggests that there are real challenges to address in some areas.
(d) Only limited data is available on the breakdown of the sectors where the doses are most significant. Whilst some of the higher doses are in the general diagnostic area (probably using image intensifiers), interventional radiology and cardiology do stand out as areas of concern.

2.3 UK Data

The data for the UK in Table 3 clearly requires some explanation, as 535 is an unrealistic number for the number of exposed workers in medicine in a country of over 50 million population. UK legislation [8] makes a distinction between those who are likely to receive greater than 6 mSv in a year (“classified persons” or Category A workers). There is ample dose data available for most workers in this sector to show that they are unlikely to exceed 6 mSv in a year. Therefore to save money, employers in the medical sector have traditionally classified very few workers. This is in contrast to many other sectors.

Only the doses for classified workers are kept on the Central Index of Dose Information (CIDI) which NRPB operates on behalf of the Health and Safety Executive (HSE), the regulatory body. It is the CIDI data [9] that provided the input to the ESOREX study. However, the vast majority of the Category B workers are routinely subject to individual monitoring and dose records are kept.

Every 4 years NRPB carries out a comprehensive review of the exposure of the UK population to ionising radiation. The latest review in 1999 [10] included the data in Table 4.

Table 3 Occupational exposure in medicine in Europe in 1995 (source ESOREX [7])

Country	No of monitored workers	% of total monitored workers	No of measurably exposed medical workers	No in dose range (mSv)					Average annual individual doses (mSv)		Collective dose	
				5-10	10-15	15-20	20-50	>50	Monitored workers	Measurably exposed workers	man mSv	% of total for all workers
Denmark	6482	62	1828	11	4	1	0	0	0.18	0.63	1144	59
Finland	5388	50	868	46	13	5	8	3	0.37	2.32	2017	44
Germany	241484	73	26242	338	62	18	10	8	0.11	1.02	26682	28
Greece	5305	80	1101	74	25	9	20	1	0.51	2.48	2728	85
Iceland	540	96	129	0	1	0	1	0	-	-	-	98
Ireland	4724	80	650	0	0	0	0	0	0.04	0.26	172	72
Luxembourg	1059	73	-	0	0	0	0	0	0.20	0.55	175	79
Netherlands	22165	68	-	190	75	53	55	6	0.43	-	9570	63
Norway	7918	65	1794	75	27	14	14	0	0.36	1.60	2875	79
Spain	51555	76	46578	279	55	36	27	6	0.50	0.55	25720	54
Sweden	5530	36	-	16	1	0	0	0	0.35	-	1942	9
Switzerland	42554	70	3196	122	67	0	1	0	1.35	1.72	1325	56
UK	535	1	184	3	2	0	0	0	0.5	0.8	149	1

TABLE 4 Occupational exposure in medicine in the UK

Work category	Number of workers in dose range (mSv) 0–1	1–5	5–10	10–15	15–20	20–30	30–40	>40	Total number of workers	Annual collective dose (x 10^{-3} man Sv)	Average annual dose (mSv)
Diagnostic	10,421	198	4	2	2	2	0	0	10,629	807.1	0.08
Radiotherapy	2,902	14	3	0	0	2	1	0	2,922	233.4	0.08
Nuclear medicine	770	113	0	0	0	0	0	0	883	294.1	0.33
Main survey total	14,093	325	7	2	2	4	1	0	14,434	1,334.6	0.09
Further survey sample*	2,509	28	1	0	0	0	0	0	2,538	115.0	0.05
Survey total	16,602	353	8	2	2	4	1	0	16,972	1,449.6	0.09
UK total (estimate)	39,100	850	<50	<10	<10	<10	<10	0	40,000	4,000	0.1

* Data for a further group of all medical workers who were not separated into work areas.

The data refers to 1996 and was derived from a survey of a larger National Health Service (NHS) dosimetry services. It can be seen that the average annual doses are generally very low (0.09 mSv in a year) compared with similar figures from the ESOREX project and UNSCEAR. Medical Physicists and Qualified Experts have for years had a high profile and influence in the medical sector which is reflected in these figures. Nevertheless some groups do have noticeably higher doses than others, eg those involved in Nuclear Medicine. Table 5 gives a more detailed breakdown of exposures in this area by occupational group. The largest contribution is probably from organ imaging using technectium-99m. Tables 6 and 7 provide similar data for diagnostic radiology and radiotherapy departments respectively. In the former Cardiologists stand out in terms of average individual dose and numbers in the higher dose distributions.

TABLE 5 Occupational exposure in diagnostic radiology departments

Occupational group	Number of workers in dose range (mSv) 0–1	1–5	5–10	10–15	15–20	20–30	>30	Total number of workers	Annual collective dose(x 10^{-3} man Sv)	Average annual dose (mSv)
Main sample										
Radiologists	946	53	2	0	0	1	0	1,002	192.1	0.19
Cardiologists	432	26	1	1	1	0	0	461	120.4	0.26
Other clinicians	649	7	0	0	0	0	0	656	26.4	0.04
Radiographers	4,962	62	1	0	0	0	0	5,025	242.8	0.05
Nurses	2,238	38	0	0	0	1	0	2,277	162.5	0.07
Scientists and technicians	627	4	0	1	1	0	0	633	42.3	0.07
Other staff	567	8	0	0	0	0	0	575	20.5	0.04
Total	10,421	198	4	2	2	2	0	10,629	807.1	0.08
Partial data sample										
All diagnostic groups	2,467	21	1	0	0	0	0	2,489	–	–
Dental practice	2,827	4	0	0	0	0	0	2,831	27.6	0.01

TABLE 6 Occupational exposure in radiotherapy departments

Occupational group	Number of workers in dose range (mSv)								Total number of workers	Annual collective dose (x 10^{-3} man Sv)	Average annual dose (mSv)
	0–1	1–5	5–10	10–15	15–20	20–30	30–40	>40			
Main sample											
Beam radiographers	861	3	0	0	0	1	0	0	865	52.2	0.06
Radiotherapists	239	3	0	0	0	0	1	0	243	54.8	0.23
Theatre nurses	476	5	0	0	0	0	0	0	481	23.7	0.05
Ward nurses	645	1	1	0	0	1	0	0	648	66.5	0.10
Other nurses	63	1	0	0	0	0	0	0	64	6.5	0.10
Source technicians	16	0	0	0	0	0	0	0	16	2.4	0.15
Scientists and technicians	250	1	2	0	0	0	0	0	253	25.1	0.10
Other staff	352	0	0	0	0	0	0	0	352	2.3	0.01
Total	2,902	14	3	0	0	2	1	0	2,92[illegible]	233.4	0.08
Partial data sample											
All radiotherapy staff	384	32	0	1	0	0	0	0	417	–	–

TABLE 7 Occupational exposure in nuclear medicine departments

Occupational group	Number of workers in dose range (mSv)						Total number of workers	Annual collective dose (x 10^{-3} man Sv)	Average annual dose (mSv)
	0–1	1–5	5–10	10–15	15–20	>20			
Main sample									
Pharmacists	148	20	0	0	0	0	168	59.4	0.35
Radiographers	207	55	0	0	0	0	262	139.5	0.53
Scientists and technicians	75	11	0	0	0	0	86	24.7	0.29
Clinicians	51	3	0	0	0	0	54	10.0	0.18
Nurses	54	19	0	0	0	0	73	44.5	0.61
Other staff	106	3	0	0	0	0	109	6.3	0.06
Research workers	129	2	0	0	0	0	131	9.8	0.07
Total	770	113	0	0	0	0	883	294.1	0.33
Partial data sample									
All nuclear medicine staff	918	24	0	0	0	0	942	–	–

2.4 French Data

Recent data available from France can be found in the Annual Report from OPRI; the 1999 data are summarised in table 8.

Table 8: Occupational exposure in the non nuclear industry in France in 1999 (OPRI [11])

Activity	No of persons monitored	No in dose range					Collective dose (man Sv)
		<1	1-6	6-20	20-50	>50	
Radiology	87755	86207	1189	294	48	17	9,90
Radiotherapy	7922	7621	259	35	7	0	1,41
Nuclear medicine	4053	3614	400	39	0	1	1,59
Non in vitro work	3595	3572	23	0	0	0	0,11
Dental	25672	25412	208	48	3	1	1,59
Occupation & public health	5404	5366	33	3	1	1	0,49
Veterinary	2667	2637	27	2	1	0	0,14
Non nuclear industry	22767	18763	2639	1299	60	6	18,97
Research	8095	8057	34	4	0	0	4,02
Others	5772	5695	56	20	1	0	0,40
Total	173702	166944	4868	1744	121	25	38,62

The French situation is totally different from the UK one as the number of monitored workers is very high reaching more than 100 000 individuals in the medical sector or even about 140 000 when dentists and veterinarians are included. In the latter case the medical sector accounts for 54 % of the total number of monitored individuals in the country. The dose distributions show that there are individual doses exceeding 6 mSv in all areas in the medical sector and even 20 mSv in many areas. One surprising result is the dose distribution in the dental sector where there should be negligible doses when good practices are implemented. This, of course, requires an in depth analysis of the behaviours, and raises questions about the radiological protection culture in the sector as well as how the actual dosimeters are used.

3. POSSIBLE ISSUES

As identified in the Introduction, the style of EAN Workshops is designed to be interactive with discussions leading to recommendations. To some extent the structure and title of the sessions gives some guiding framework for the Working Groups, but it has also proved to be useful to pose some questions at the beginning of the Workshop. The questions below are not exhaustive and in no way should constrain the deliberations of the Working Group. Some of the questions are focused on a session, whilst others are more general themes.

In collaboration with the International Labour Organisation (ILO), European Commission (EC), Nuclear Energy Agency (NEA) and the World Health Organisation (WHO), IAEA recently organised an International Conference on Occupational Radiation Protection "Protecting Workers against Exposure to Ionising Radiation". The findings and recommendations of the Conference stated

> "Exposure of Workers in conventional radiology, both radiodiagnosis and radiotherapy are generally well controlled. There are however new areas of medical practice, especially interventional radiology, in which very high exposures are received. Ensuring that sufficient attention is paid to control and

reduction of such exposures requires continued efforts in post graduate education and in awareness raising of the medical professions involved. The participation of health physicists in the implementation of optimisation programmes in interventional radiology is strongly recommended."

This provides a good starting point for some of our discussions and there are some questions that arise from it.

(a) There are several papers at the Workshop that address radiological protection aspects of new technologies, particularly in interventional radiology, nuclear medicine with the use of new radioisotopes and positron emission tomography

New technologies and procedures provide radiation protection challenges : are there issues where co-operative research would be useful?

(b) The dose data suggests very varied levels of achievement in implementing the ALARA principle in occupational medical exposure, both between nations and down to the individual hospital level. The IAEA findings and UK experience suggested that the input from Health Physicists is important.

Do Qualified Experts and Radiation Protection Supervisors have a high enough profile and influence within medical establishments, both large and small? If not what can be done to improve the situation?

(c) Perhaps allied to the previous question is the issue of radiation protection safety culture in medical establishments.

There is often a link between the standard of radiological control of patient exposure and occupational exposure. Is that link widely recognised and if not, what initiatives to improve safety culture can be identified?

(d) Appropriate training of staff, at all levels is a fundamental building block in the attainment of a good radiation protection safety culture. There are a number of aspects to this which need to be addressed.

(i) Is radiation protection covered to a sufficient extent in the professional training of the various mainstream occupations associated with medical exposure? If not, how can this be improved?
(ii) New Technology and procedures can lead to professions and occupational groups that are unfamiliar with radiation protection becoming new users : are there adequate training arrangements?
(iii) Update and refresher training is important : are there sufficient facilities for this and could we make more use of e-technology to make it available?

(e) Accidents and incidents occur in all sectors of use and there is much to be learned from them.

How can we improve the feedback process so that we learn lessons from accidents and incidences and particularly how should we make the information available to the direct users, who care spread across diverse establishments?

(f) A number of papers at the Workshop address the problems of extremity monitoring, which is sometimes overlooked.

Are there concerted actions that could improve the monitoring and control of extremity exposure?

(g) The production and transport of radiopharmaceuticals involves a series of different employers; the producer, possibly several freight and handling companies and a range of people in hospitals and clinics. Each has a range of driving forces e.g. economic, operational etc. that may be mutually conflicting. This and the dose rates present around transport package, provides the potential for doses that are a significant fraction of the dose limit.

Is there scope for improvements in dose control in the production and transport of radiopharmaceuticals and if so how should this be focussed?

Conclusion

There are many good aspects of the control of occupational exposure in medicine and equally there are some areas where improvements could be made in order to achieve ALARA. This Workshop provides an opportunity for exchange of information, to learn from the good and bad points and to identify initiatives that would facilitate this in the future.

REFERENCES

1. EAN. The 2nd European ALARA Workshop: Good Practices in Industry and Research". 23-25 November 1998, Chilton UK. Proceedings in Workshops section on http://ean.cepn.asso.fr

2. Croft, J.R. Overview of national and international systems for the dissemination of feedback experience on radiological accidents. These proceedings.

3. EAN. The 3rd EAN ALARA Workshop : Managing Internal Exposures. 15-18 November 1999, Neuherberg, Germany. Proceedings in Workshops section on http://ean.cepn.asso.fr.

4. EAN. The 5th EAN ALARA Workshop : Industrial Radiography – Improvements in Radiation Protection. 17-19 October, Rome, Italy. Proceedings in Workshops section http://ean.cepn.assoc.fr.

5. EAN. Newsletters Nos 1-11, in Newsletters section http://ean.cepn.asso.fr.

6. UNSCEAR. Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation : 2000 Report to the General Assembly. Vol 1. United Nations, New York, 2000.

7. Frasch G and Anatschkowa E. European Study of Occupational Radiation Exposure. Contract No. 96-ET-005. BfS 1998.

8. Ionising Radiations Regulations 1999, SI 1999/3232, Stationary Office, London, 1999.

9. HSE. Central Index of Dose Information: Summary Statistics available at http://www.hse.gov.uk/hthdir/noframes.

10. Hughes, J.S. Ionising Radiation Exposure of the UK Population : 1999 Review. NRPB-R311, Chilton, 1999.

11. OPRI, 1999 Annual report, Le Vésinet, France, 2000